

Early Results from the MODIS Atmosphere Algorithms



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Outline

- o Physical principles behind the remote sensing of cloud, aerosol, and atmospheric parameters**
- o MODIS atmosphere products**
- o Granule level (5 min.) product examples**
- o Global examples**
- o Summary**

Global Level-1B Composite Image

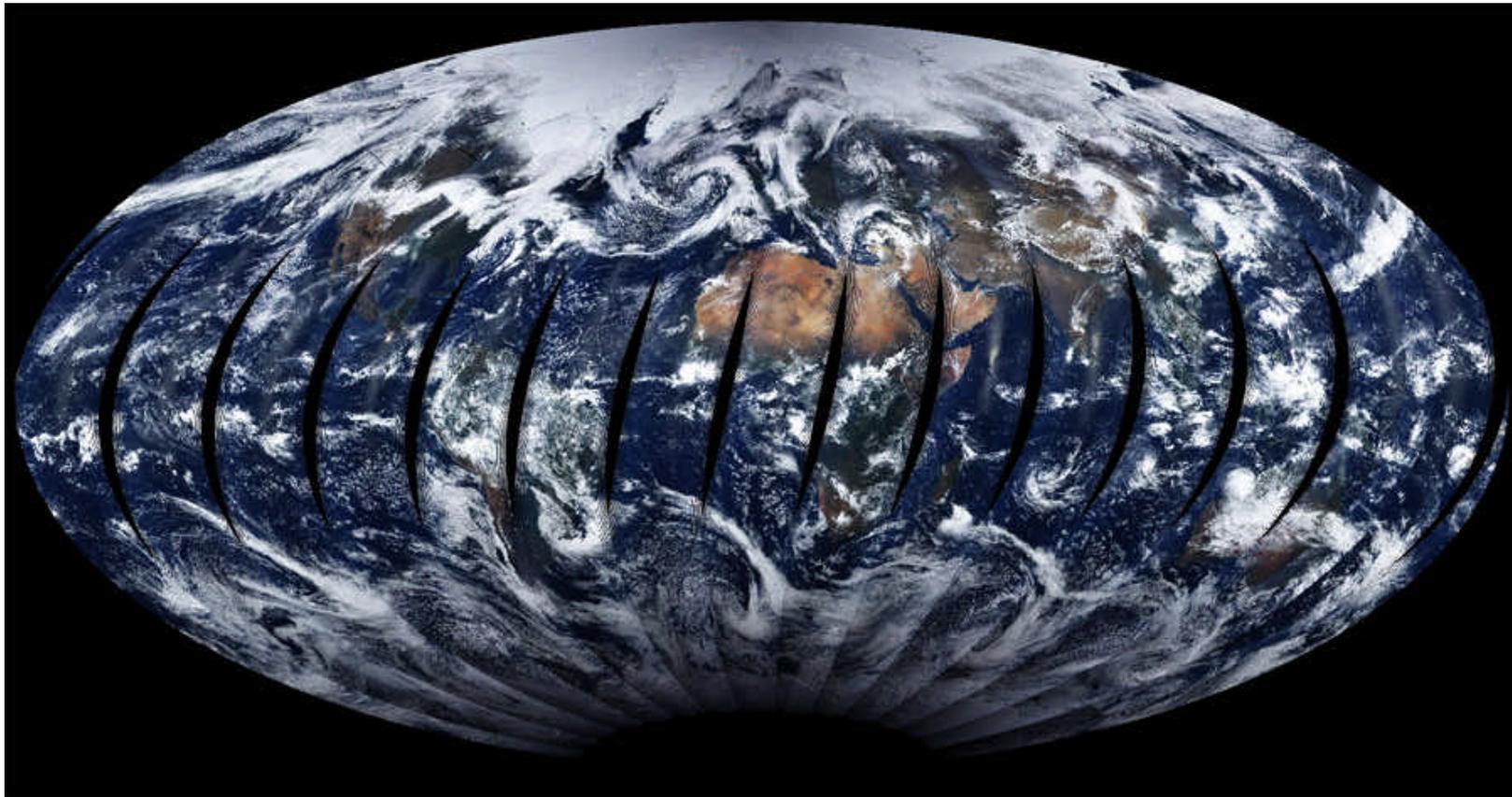


April 19, 2000

R = 0.65 μm

G = 0.56 μm

B = 0.47 μm



MODIS Atmosphere Products



o Pixel-level (level-2) products

- Cloud mask for distinguishing clear sky from clouds (288 @ 47.4 MB/file)
- Cloud radiative and microphysical properties (288 @ 44.6 MB/file)
 - » Cloud top pressure, temperature, and effective emissivity
 - » Cloud optical thickness, thermodynamic phase, and effective radius
 - » Thin cirrus reflectance in the visible
- Aerosol optical properties (144 @ 10.5 MB/file)
 - » Optical thickness over the land and ocean
 - » Size distribution (parameters) over the ocean
- Atmospheric moisture and temperature gradients (288 @ 32.3 MB/file)
- Column water vapor amount (288 @ 12.7 MB/file)

o Gridded time-averaged (level-3) atmosphere product

- Daily, 8-day, and monthly products (409.2, 781.9, 781.9 MB)
- $1^\circ \times 1^\circ$ equal angle grid
- Mean, standard deviation, marginal probability density function, joint probability density functions

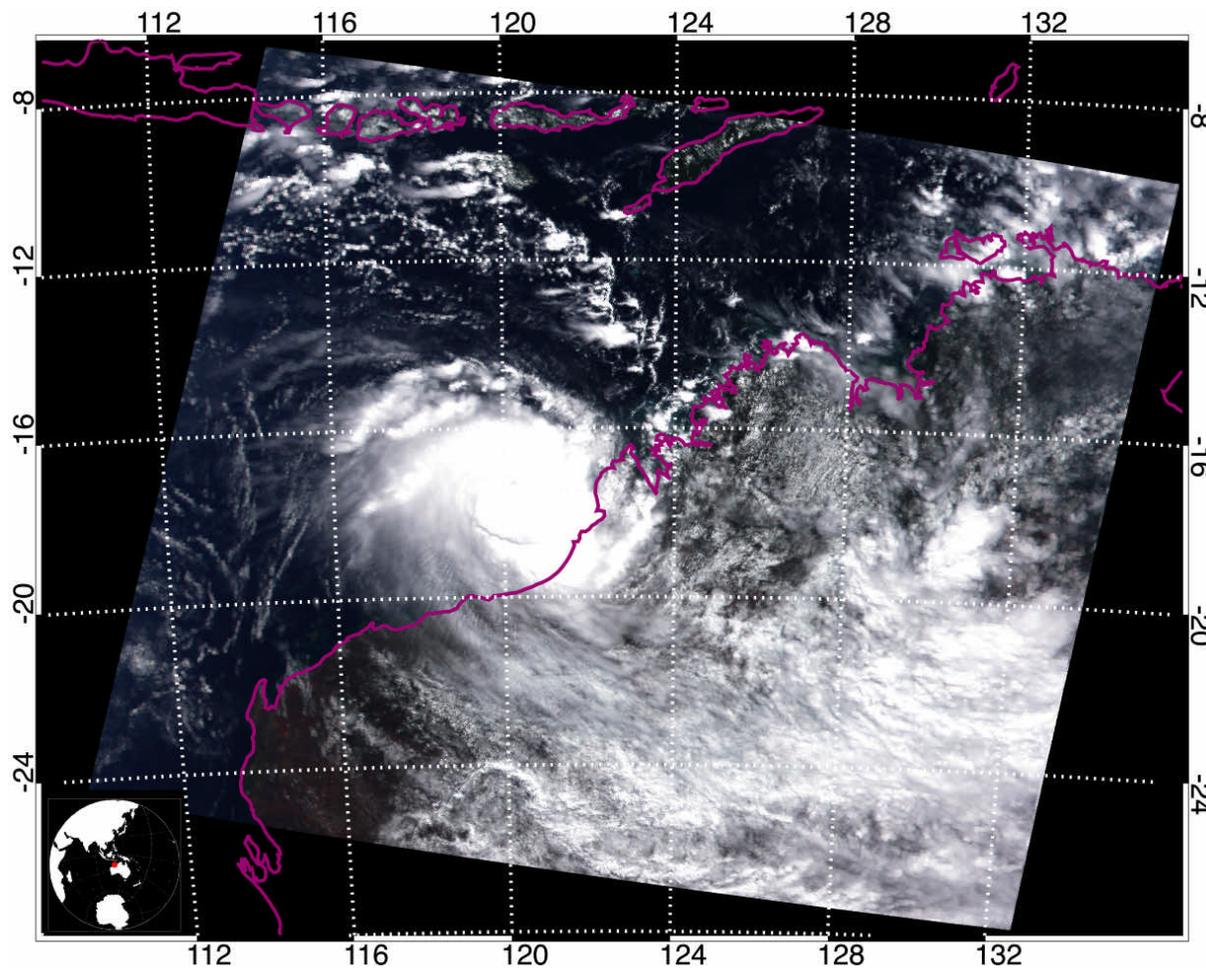
o <http://modis-atmos.gsfc.nasa.gov>

Cloud Mask

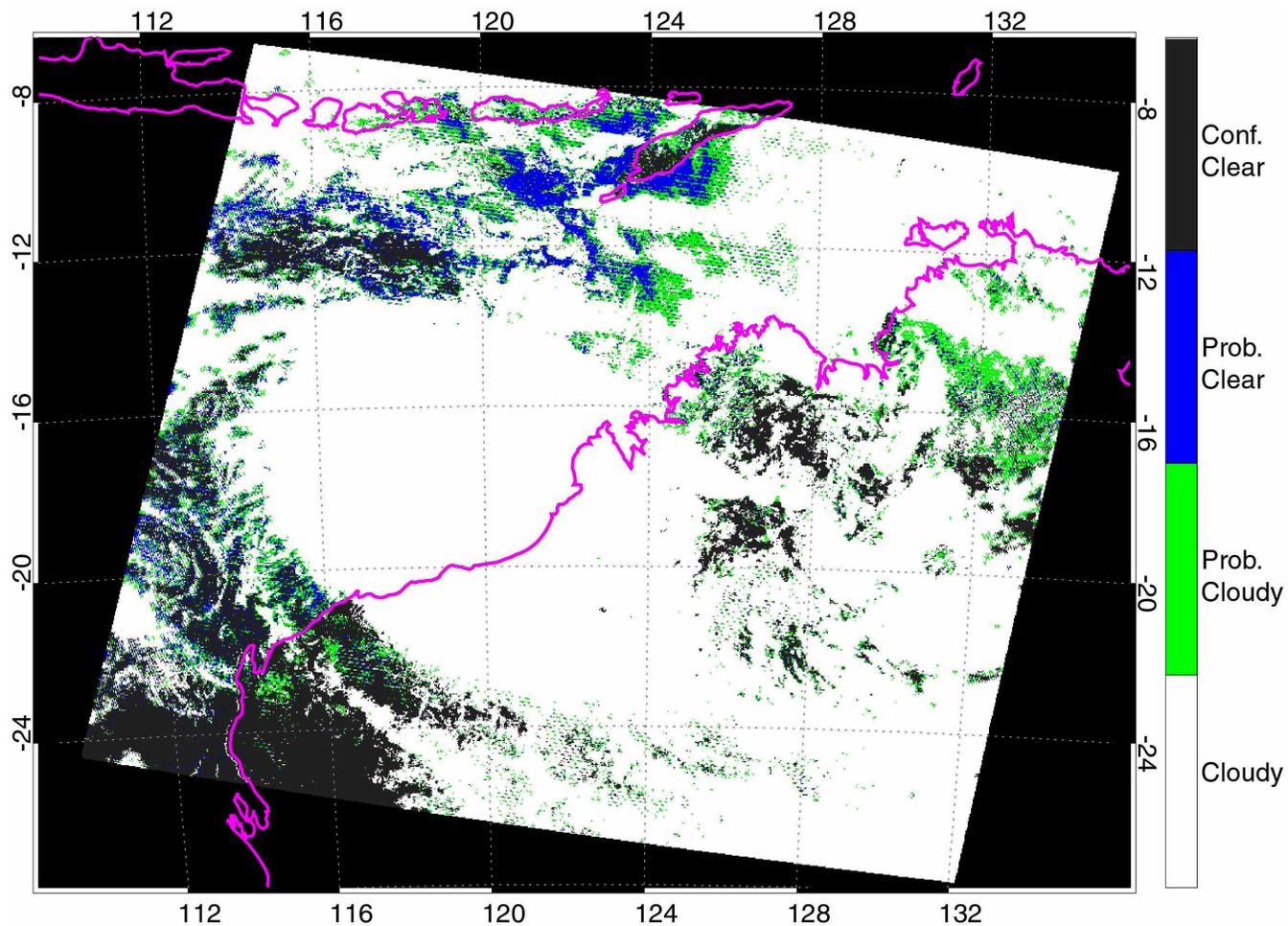


- MODIS cloud mask uses multispectral imagery to indicate whether the scene is clear, cloudy, or affected by shadows
- Cloud mask is input to rest of atmosphere, land, and ocean algorithms
- Mask is generated at 250 m and 1 km resolutions
- Mask uses **17 spectral bands** ranging from 0.55-13.93 μm (including new 1.38 μm band)
 - 11 different spectral tests are performed, with different tests being conducted over each of 5 different domains (land, ocean, coast, snow, and desert)
 - temporal consistency test is run over the ocean and at night over the desert
 - spatial variability is run over the oceans
- Algorithm based on radiance thresholds in the infrared, and reflectance and reflectance ratio thresholds in the visible and near-infrared
- Cloud mask consists of **48 bits of information** for each pixel, including results of individual tests and the processing path used
 - bits 1 & 2 give combined results (confident clear, probably clear, probably cloudy, cloudy)

Level-1B Image of Tropical Cyclone Rosita off Western Australia



Cloud Mask off Western Australia



Cloud Product



Overview

- o Top of the “food chain,” ingesting:
 - Individual cloud mask tests to determine processing path (*decision tree*)
 - Cloud top properties from MOD06
 - Ancillary data sets
 - » Ecosystem maps → surface reflectance
 - » NISE → snow/ice ecosystem
 - » NCEP → atmospheric correction
- o Optical thickness and effective radius retrieval
 - Daytime retrieval of cloud optical thickness & effective particle radius
 - » Multi-wavelength reflected solar and emitted thermal radiation measurements
 - » Wide variety of surfaces (land, ocean, desert, snow/sea ice)
 - » Water and ice clouds

Decision Tree for Cloud Retrievals



**Results of individual cloud mask tests +
Cloud mask ecosystem map**

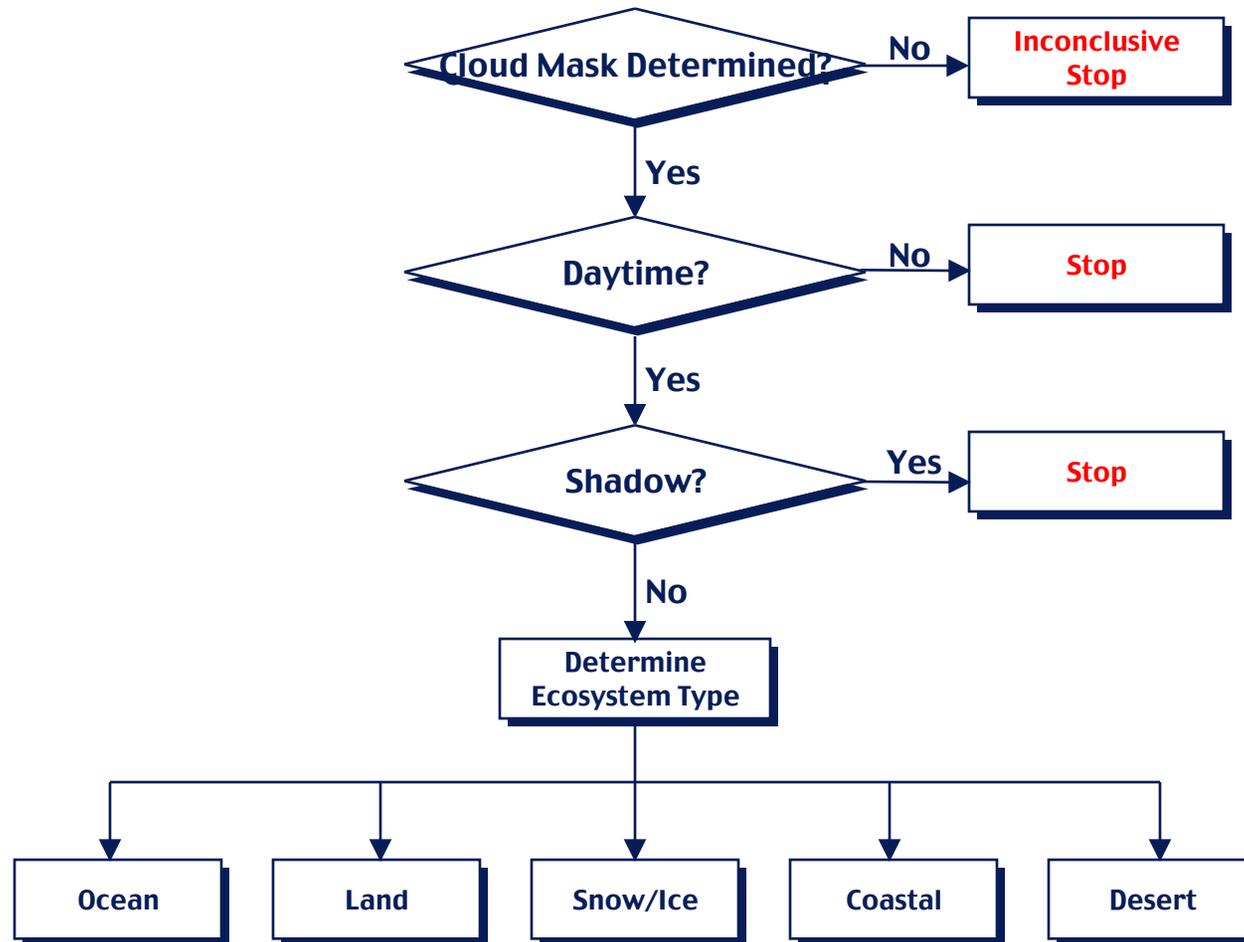


Decision Tree

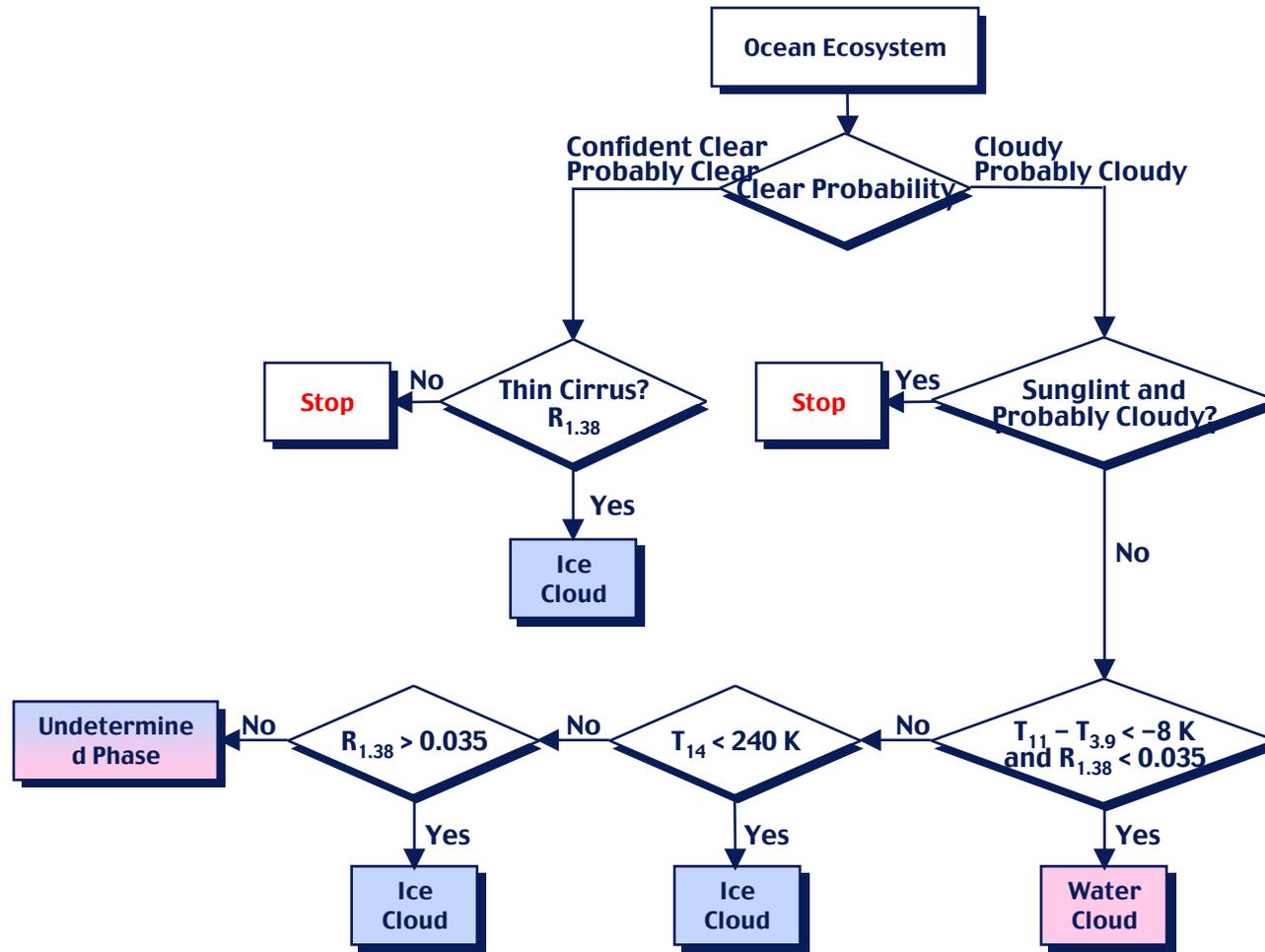


**When to retrieve +
Estimate of cloud phase**

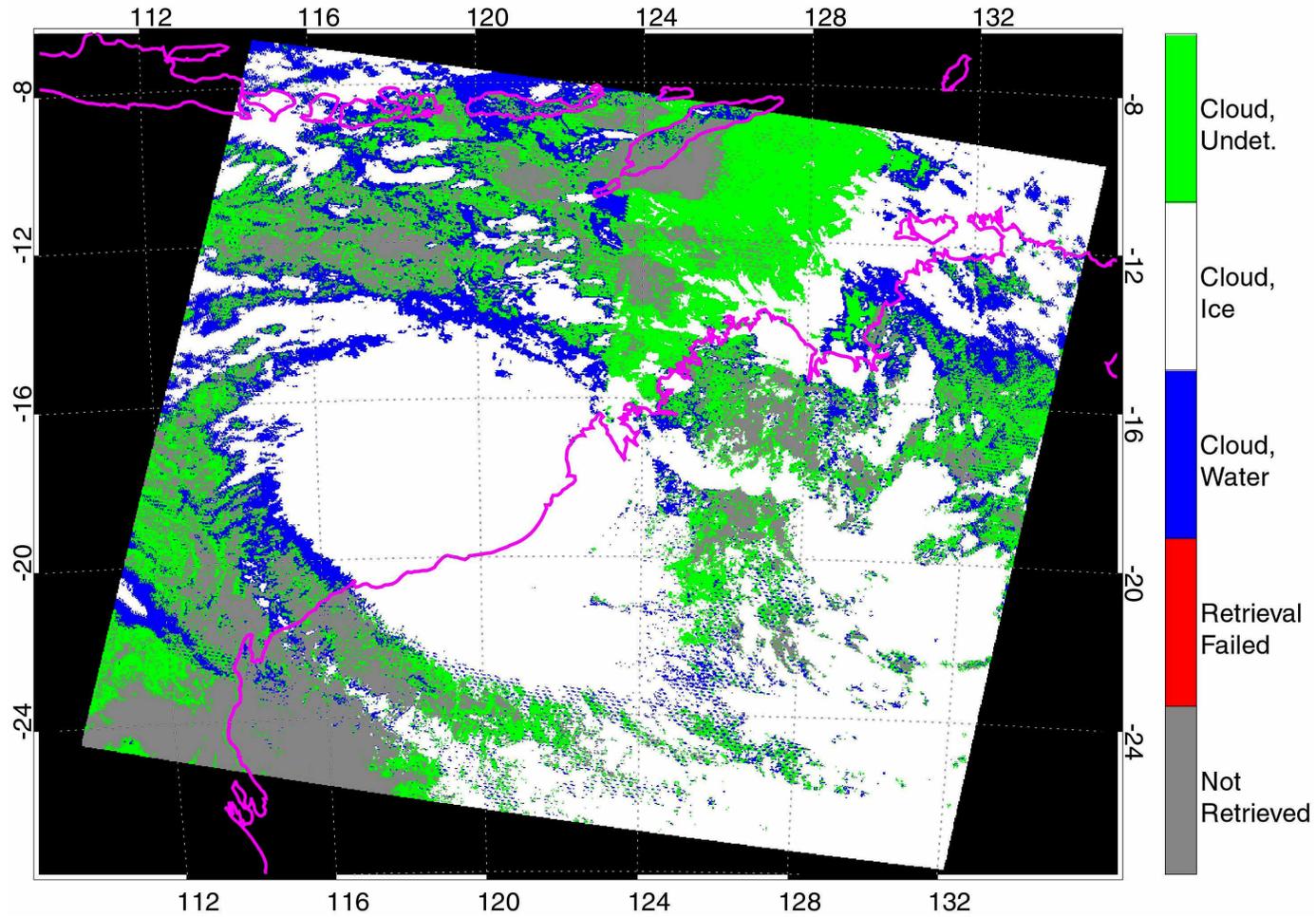
Cloud Phase Decision Tree – Processing Path



Cloud Phase Decision Tree – Ocean Processing Example



Cloud Phase Decision Tree Results



Cloud Properties

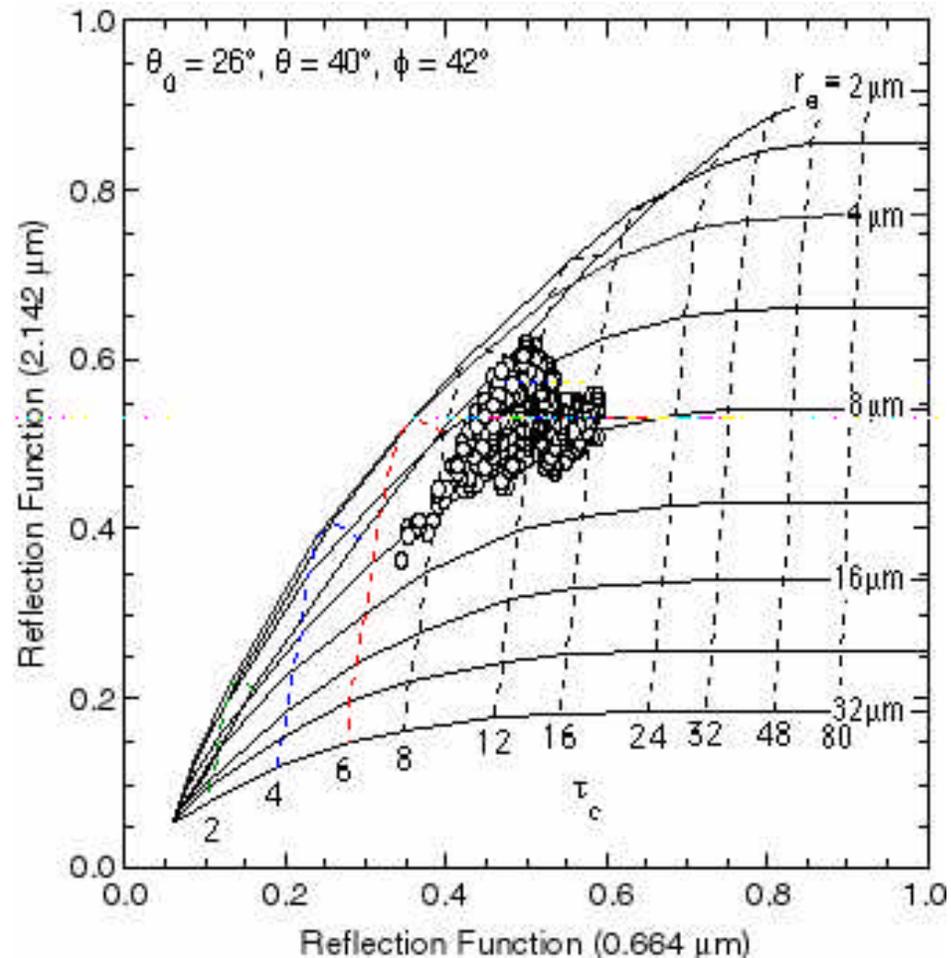


- o **Twelve MODIS bands are utilized to derive cloud properties**
 - **0.65, 0.86, 1.24, 1.38, 1.64, 2.13, 3.75, 8.55, 11.03, 12.02, 13.34, and 13.64 μm**
 - **Visible and near-infrared bands**
 - » **daytime retrievals of cloud optical thickness and effective radius**
 - » **1.6 μm band will be used to derive thermodynamic phase of clouds during the daytime (post-launch)**
 - **Thermal infrared bands**
 - » **determination of cloud top properties, including cloud top altitude, cloud top temperature, and thermodynamic phase**

Retrieval of τ_c and r_e



- The reflection function of a nonabsorbing band (e.g., 0.66 μm) is primarily a function of optical thickness
- The reflection function of a near-infrared absorbing band (e.g., 2.14 μm) is primarily a function of effective radius
 - clouds with small drops (or ice crystals) reflect more than those with large particles
- For optically thick clouds, there is a near orthogonality in the retrieval of τ and r using a visible and near-infrared band



Weighting Functions for CO₂ Slicing



o CO₂ slicing method

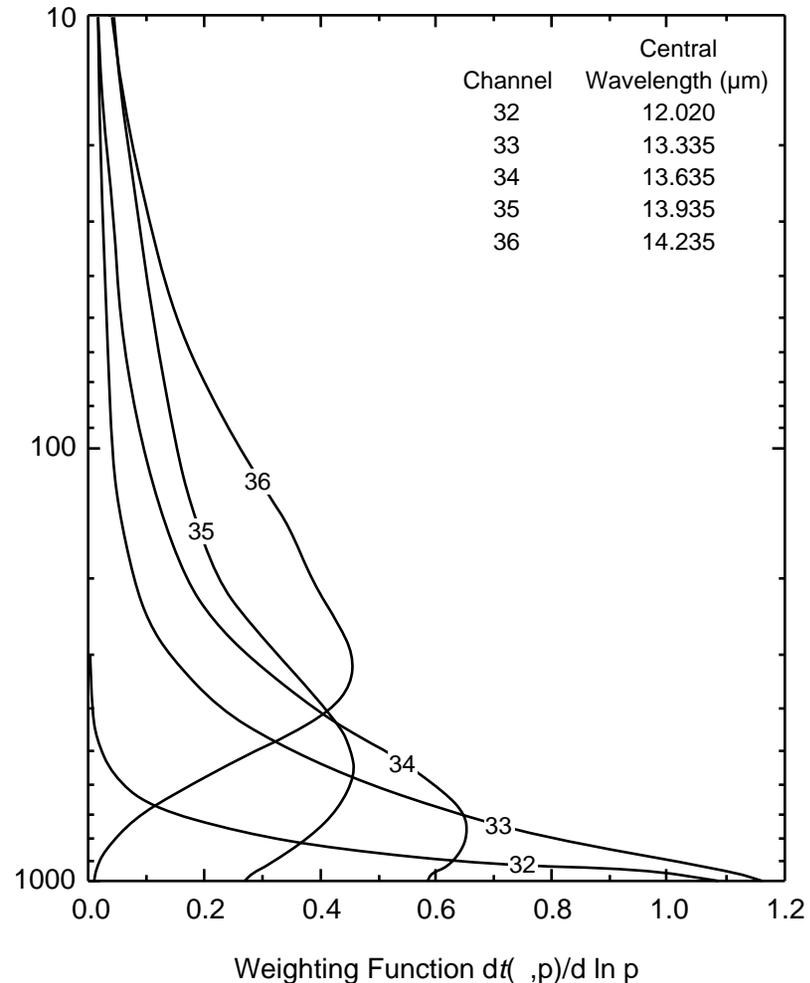
- ratio of cloud forcing at two nearby wavelengths
- assumes the emissivity at each wavelength is same, and cancels out in ratio of two bands

o The more absorbing the band, the more sensitive it is to high clouds

- technique the most accurate for high and middle clouds

o MODIS will be the first sensor to have CO₂ slicing bands at high spatial resolution (5 km)

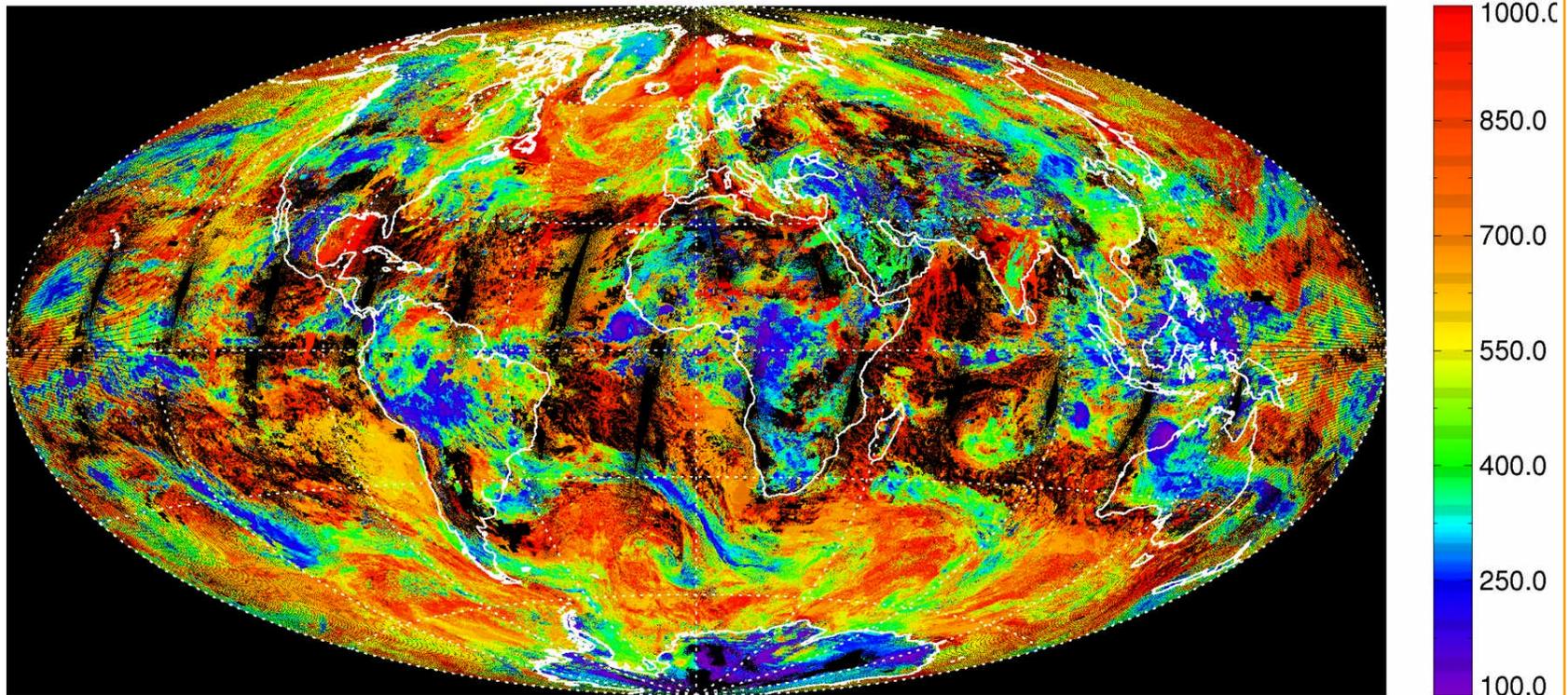
- technique has been applied to HIRS data for ~20 years



Global Cloud Top Pressure



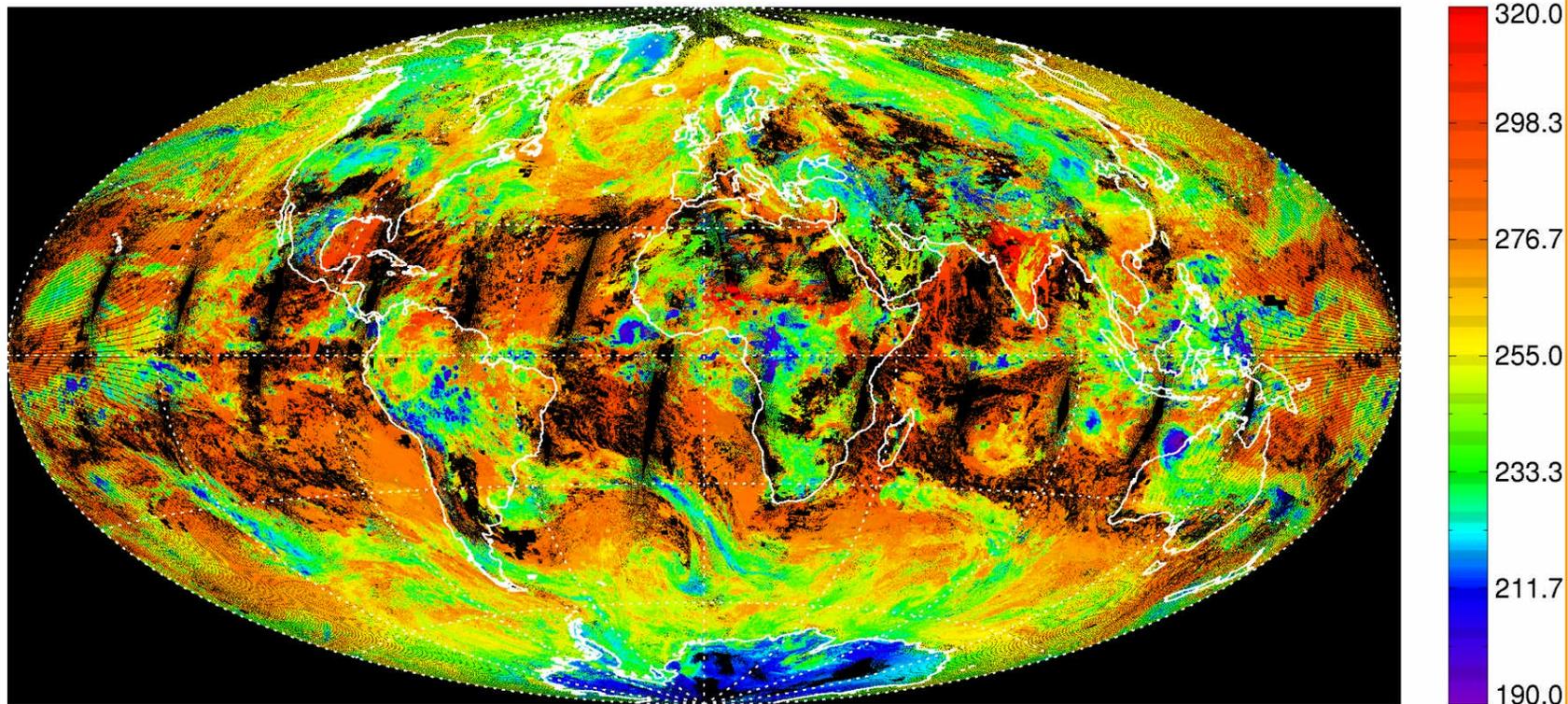
April 19, 2000



Global Cloud Top Temperature



April 19, 2000

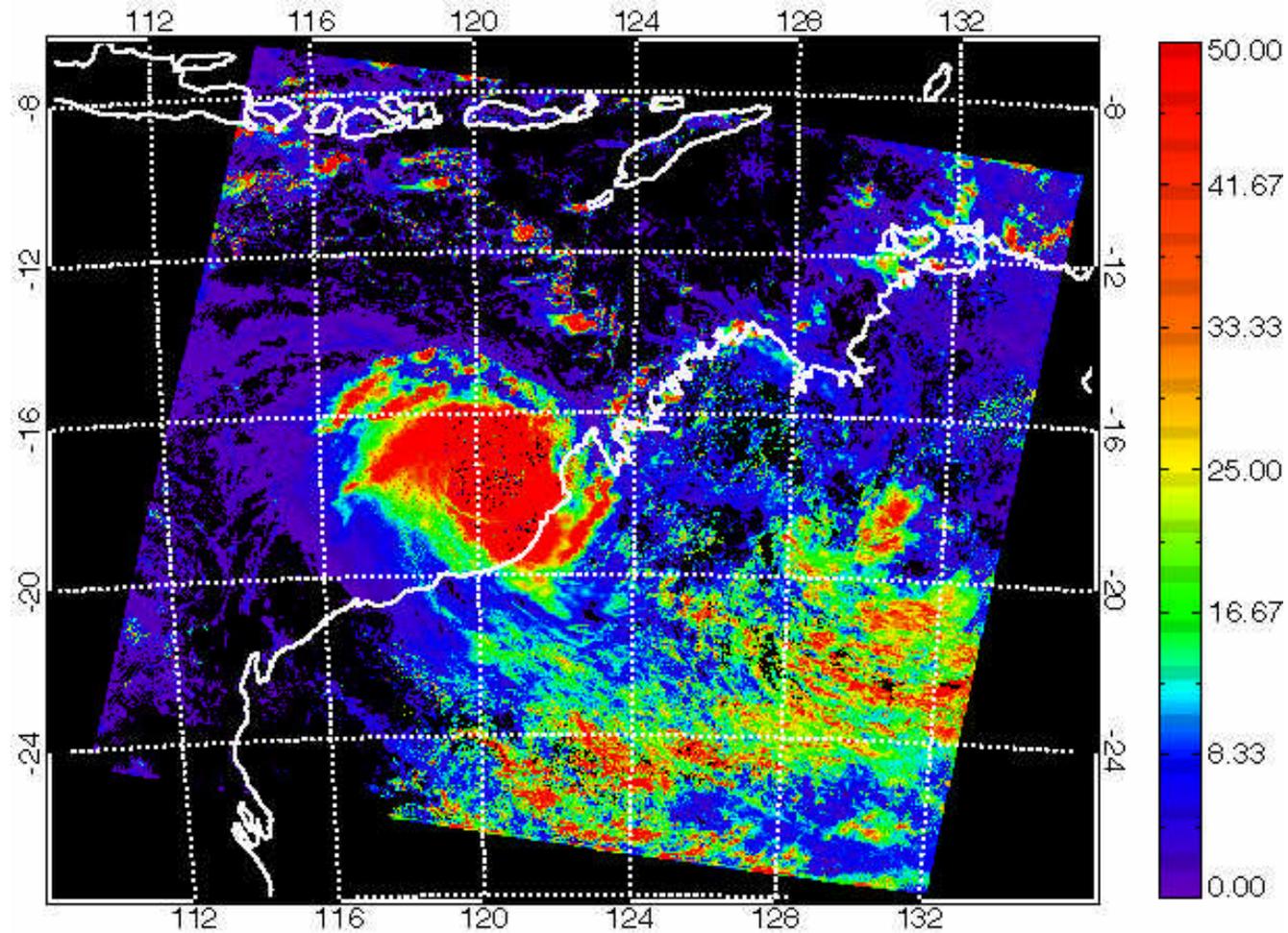


Ecosystem Map

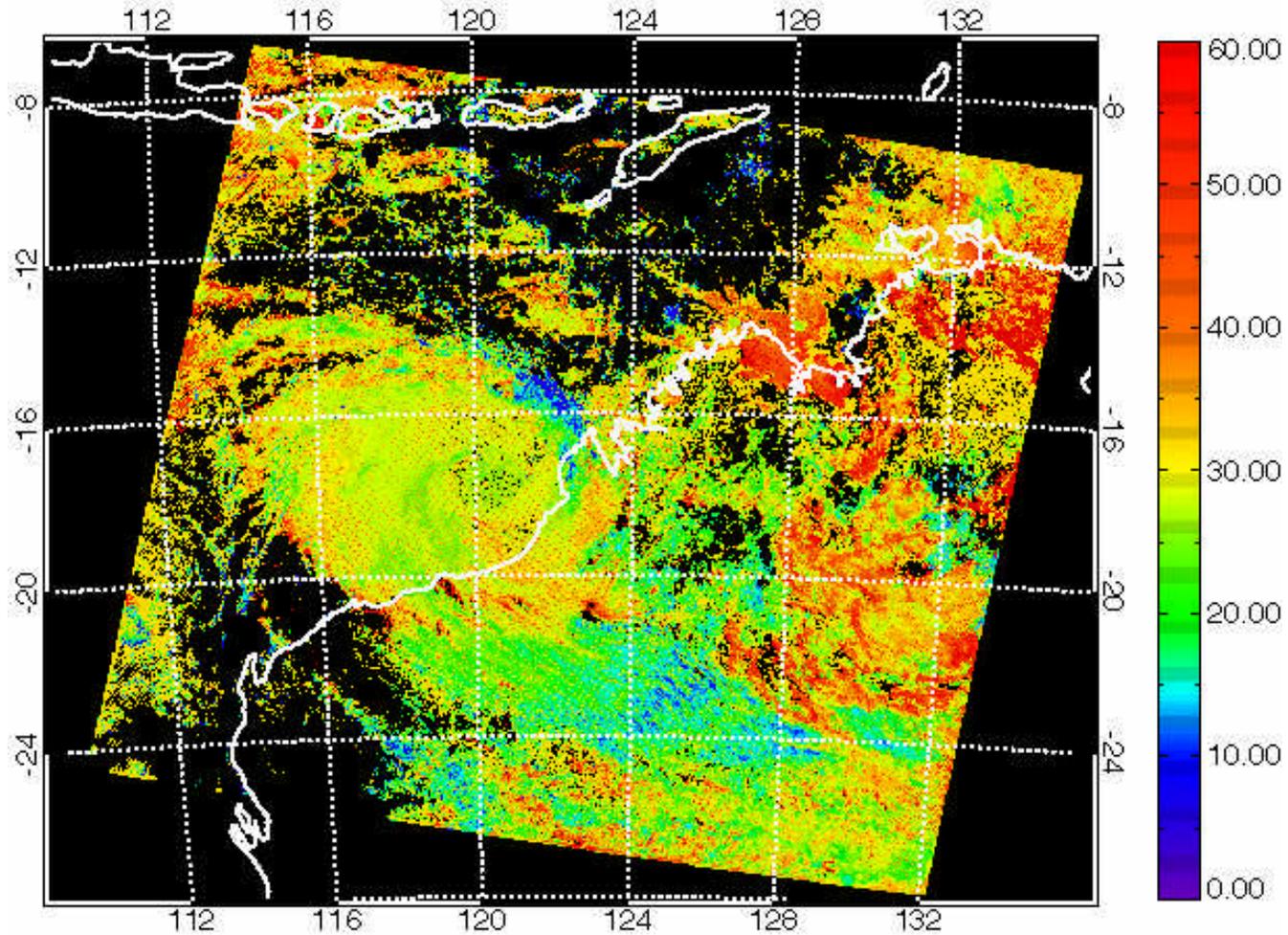


IGBP 1-minute Ecosystem Map

Cloud Optical Thickness



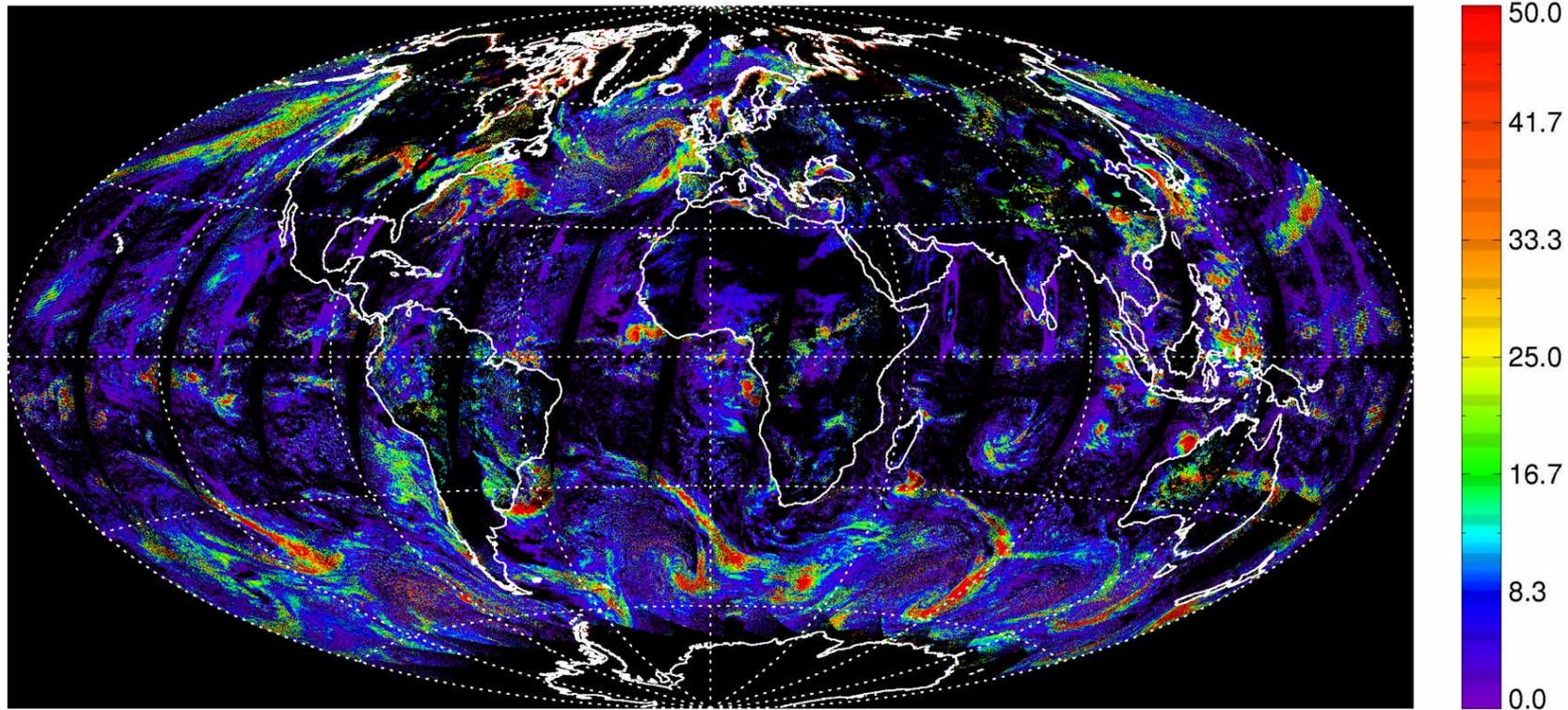
Cloud Effective Radius



Global Cloud Optical Thickness



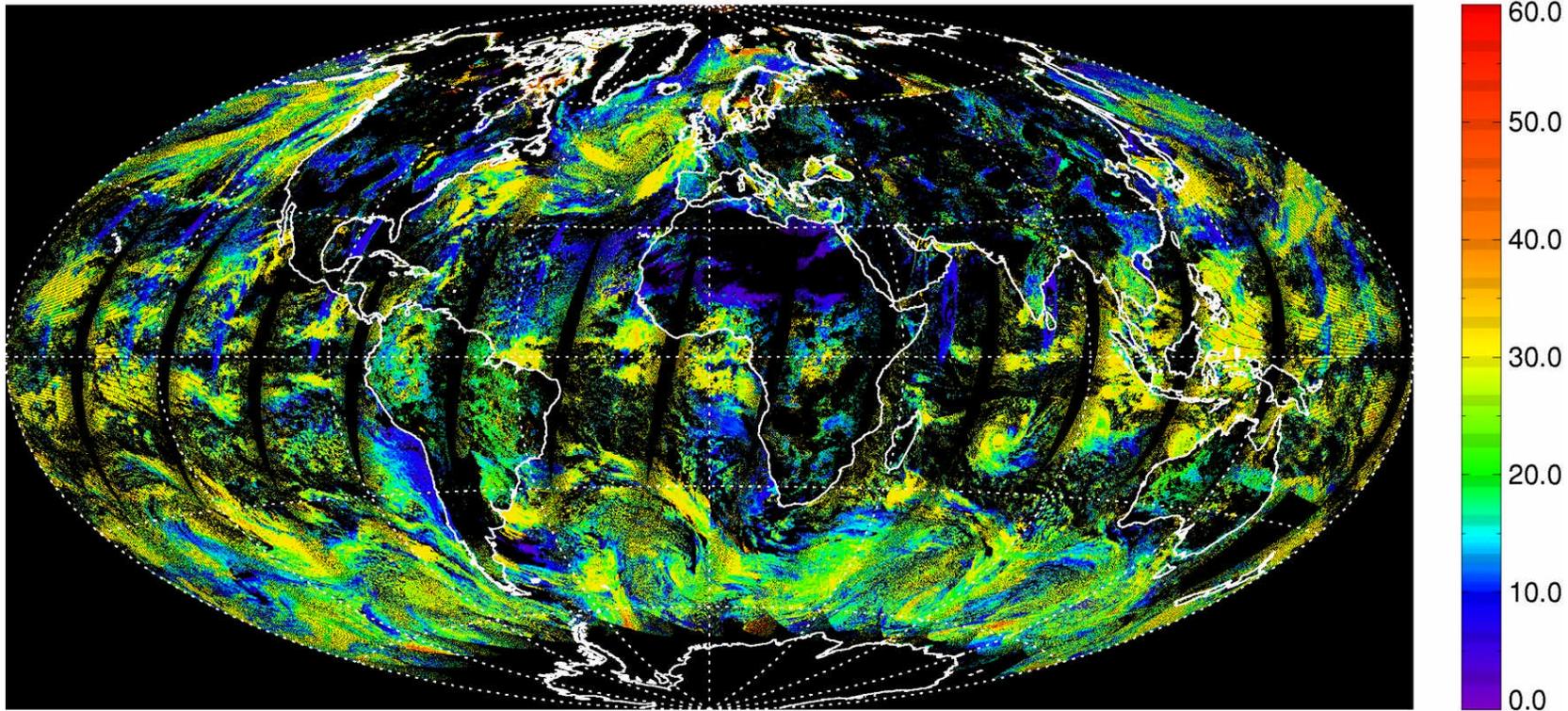
April 19, 2000



Global Cloud Effective Radius



April 19, 2000

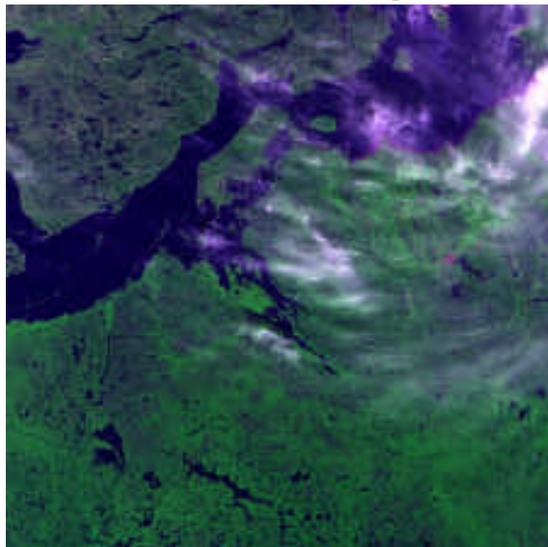


Correction of Imagery for Thin Cirrus

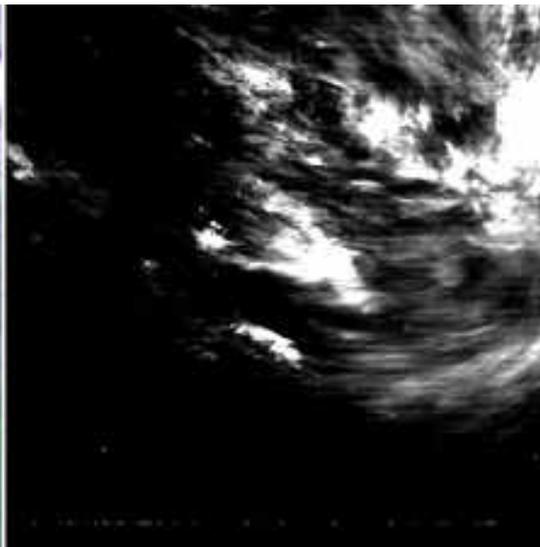


Canada
September 2, 2000

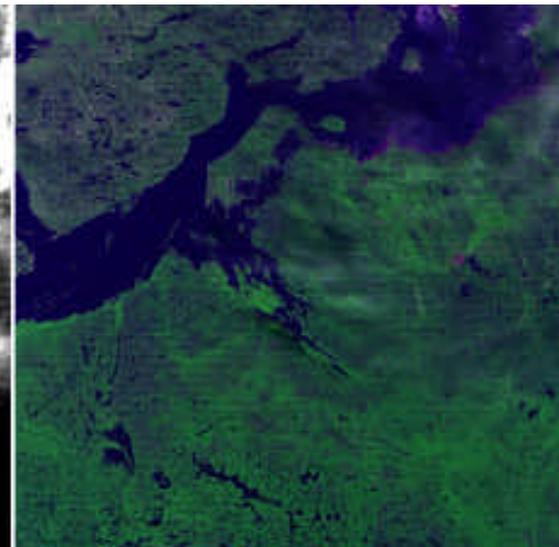
Uncorrected Image



Cirrus Image (1.38 μm)



Cirrus Corrected Image



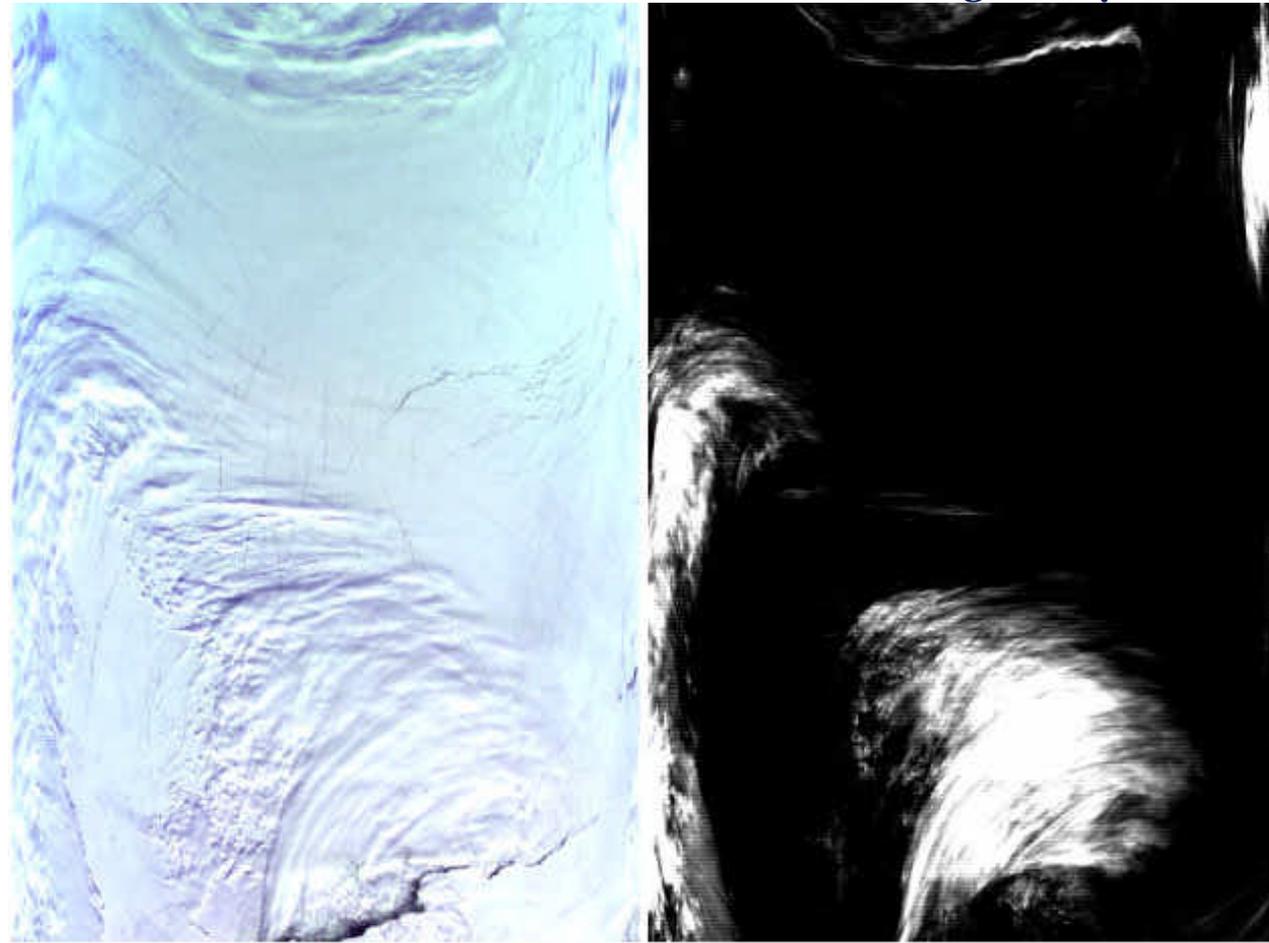
Identification of Clouds in Polar Regions



Arctic
April 19, 2000

R: 0.65, G: 0.86, B: 0.46

Cirrus Image (1.38 μm)

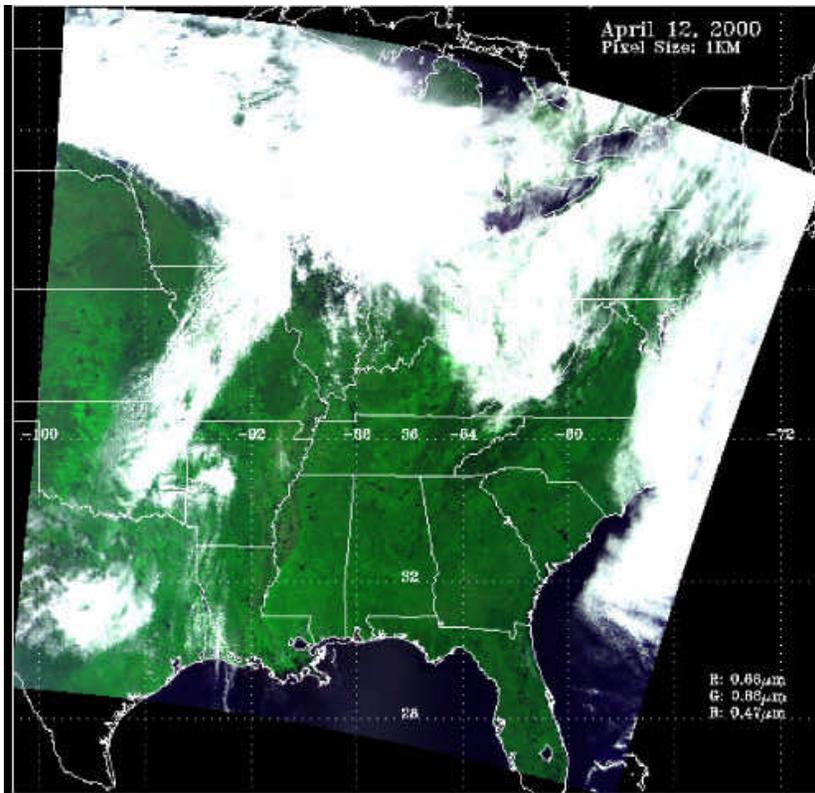


Atmospheric Water Vapor

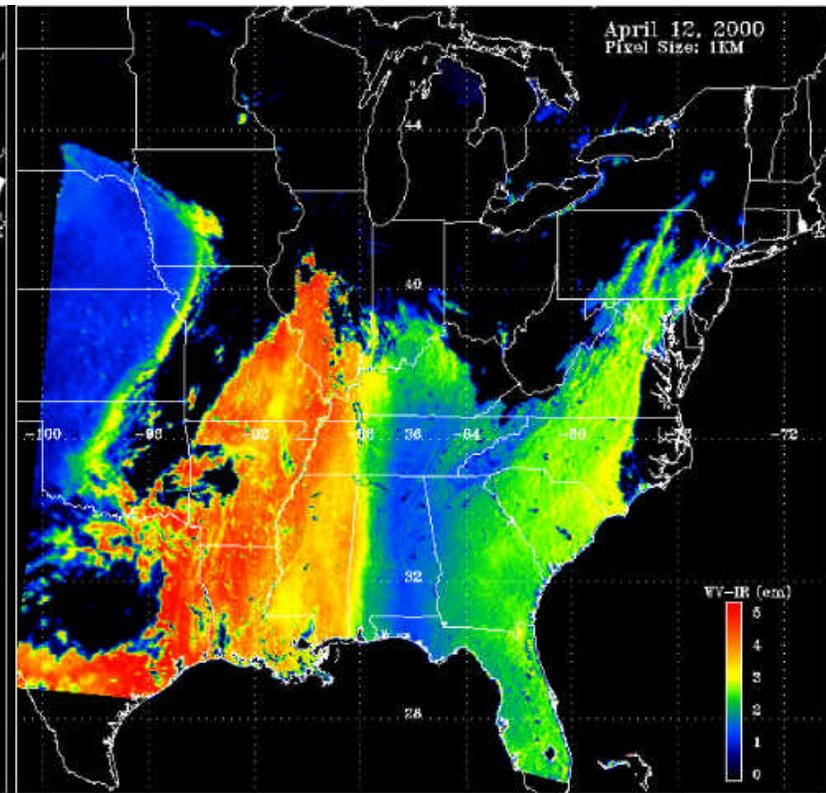


April 12, 2000

R: 0.65, G: 0.86, B: 0.46



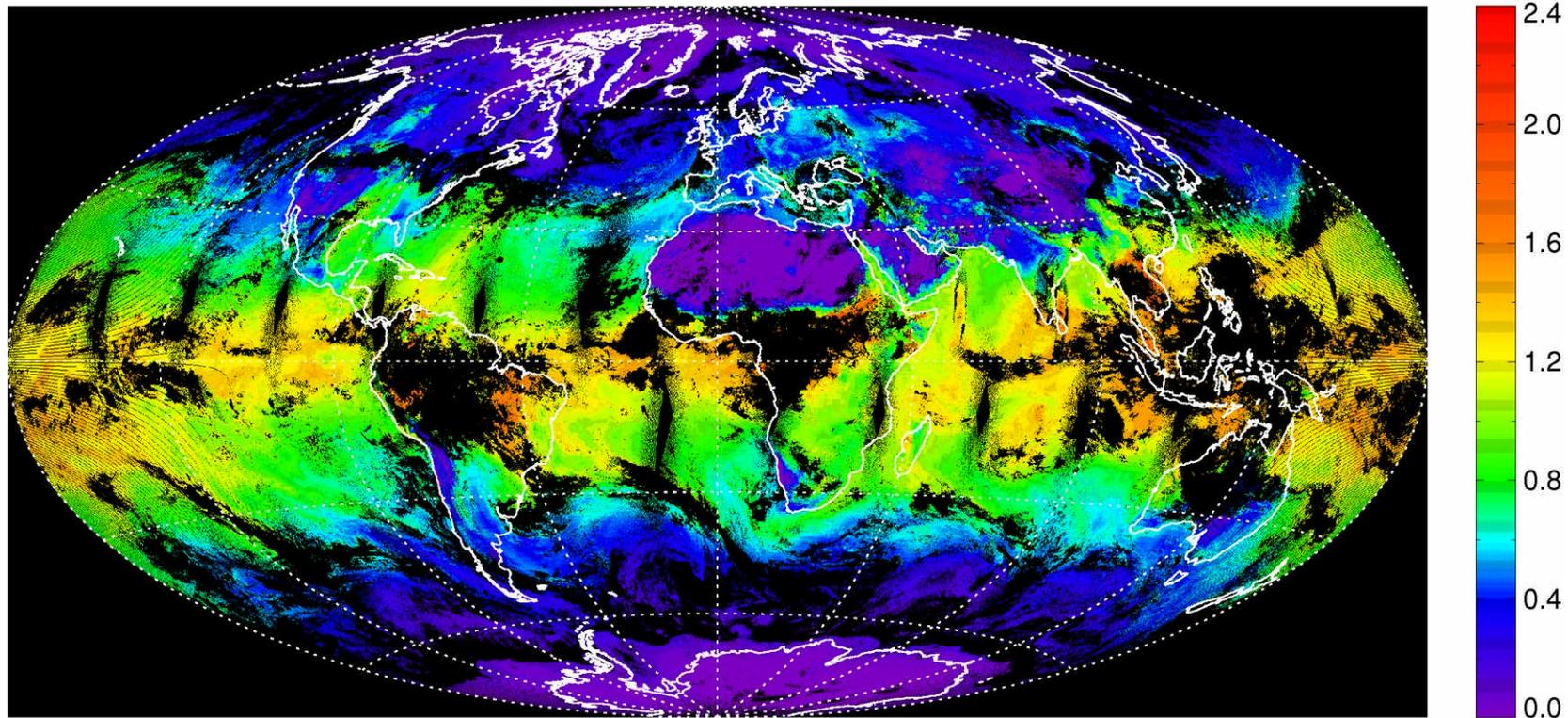
Precipitable Water Vapor (cm)



Global Atmospheric Water Vapor



April 19, 2000



Aerosol Properties

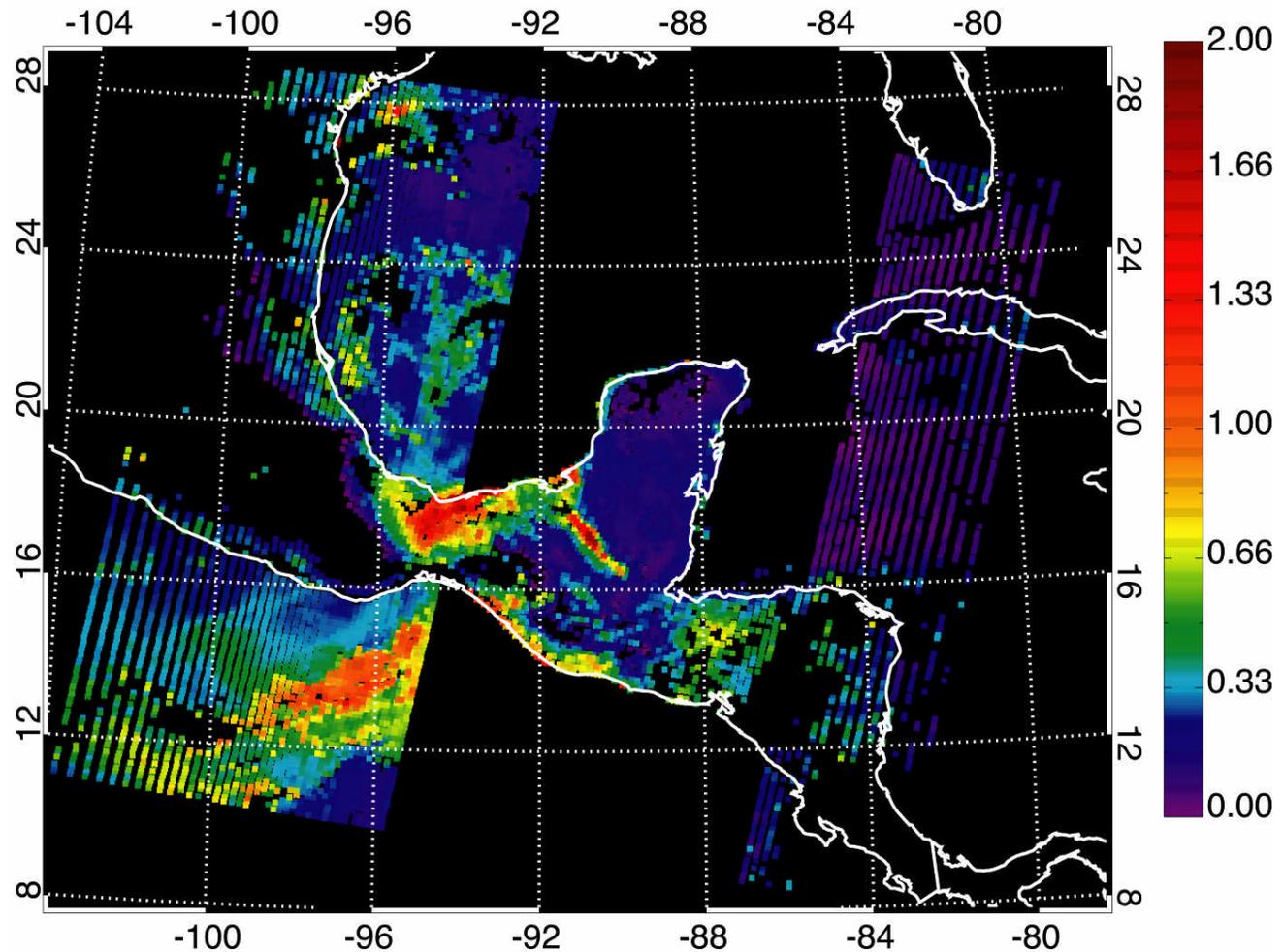


- o **Seven MODIS bands are utilized to derive aerosol properties**
 - **0.47, 0.55, 0.65, 0.86, 1.24, 1.64, and 2.13 μm**
 - **Ocean**
 - » **reflectance contrast between cloud-free atmosphere and ocean reflectance (dark)**
 - » **aerosol optical thickness (0.47-2.13 μm)**
 - » **size distribution characteristics (ratio between the assumed two log-normal modes, and the mean size of each mode)**
 - **Land**
 - » **dense dark vegetation and semi-arid regions determined where aerosol is most transparent (2.13 μm)**
 - » **contrast between Earth-atmosphere reflectance and that for dense dark vegetation surface (0.47 and 0.66 μm)**
 - » **enhanced reflectance and reduced contrast over bright surfaces (post-launch)**
 - » **aerosol optical thickness (0.47 and 0.66 μm)**

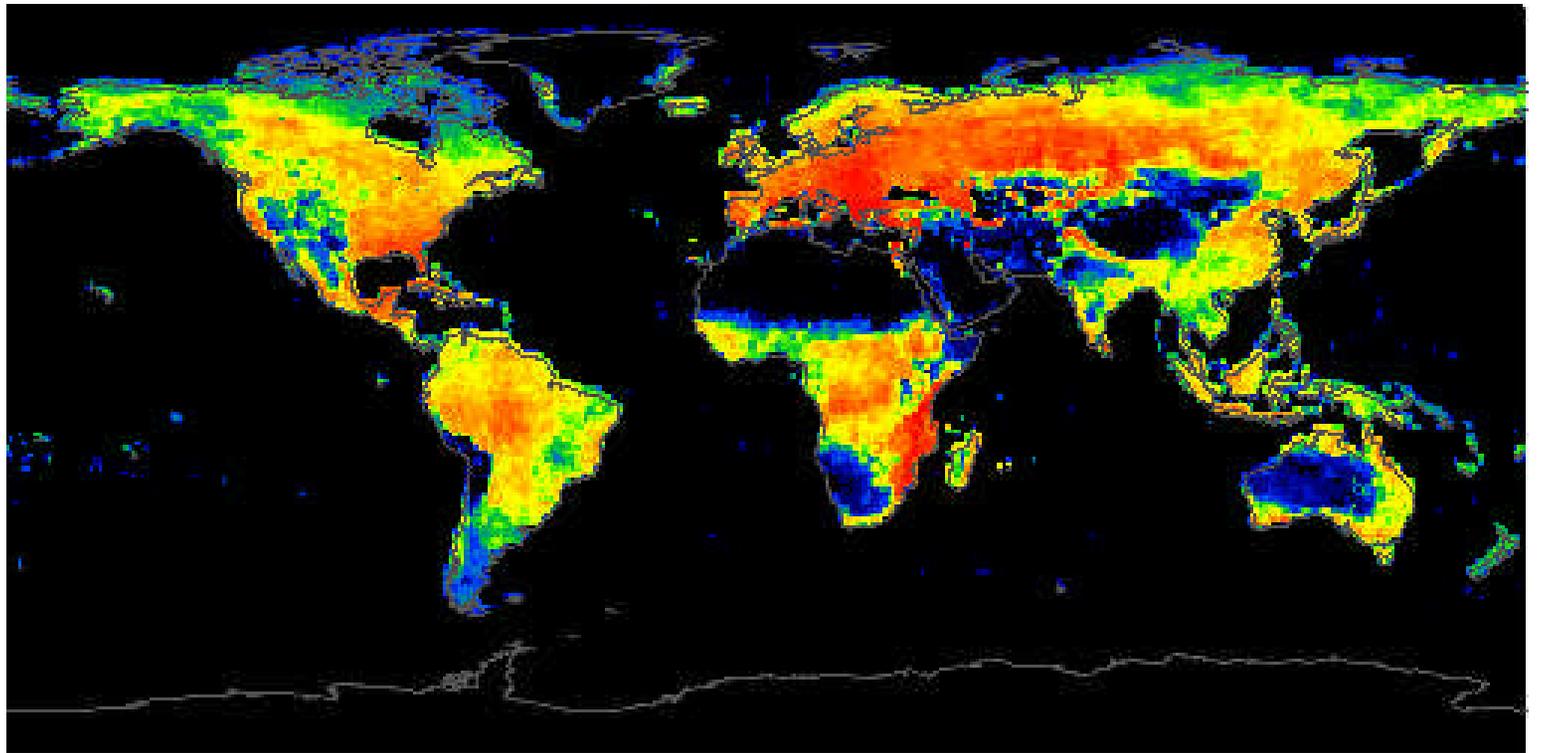
Aerosol Optical Thickness



MODIS
April 19, 2000



Frequency of Aerosol Retrievals

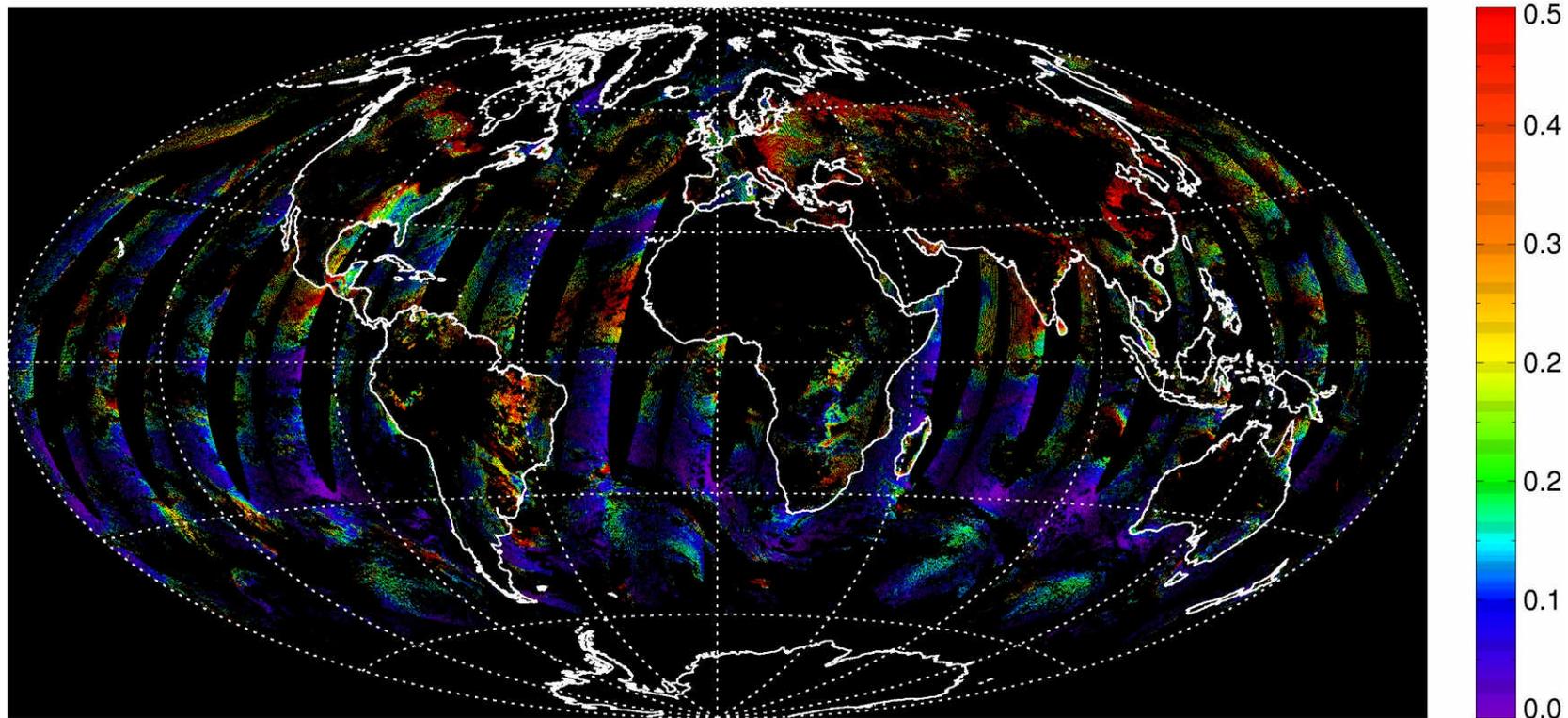


Fraction of Aerosol Retrievals for 150 days

Global Aerosol Optical Thickness



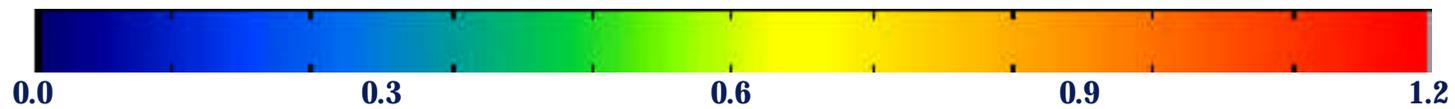
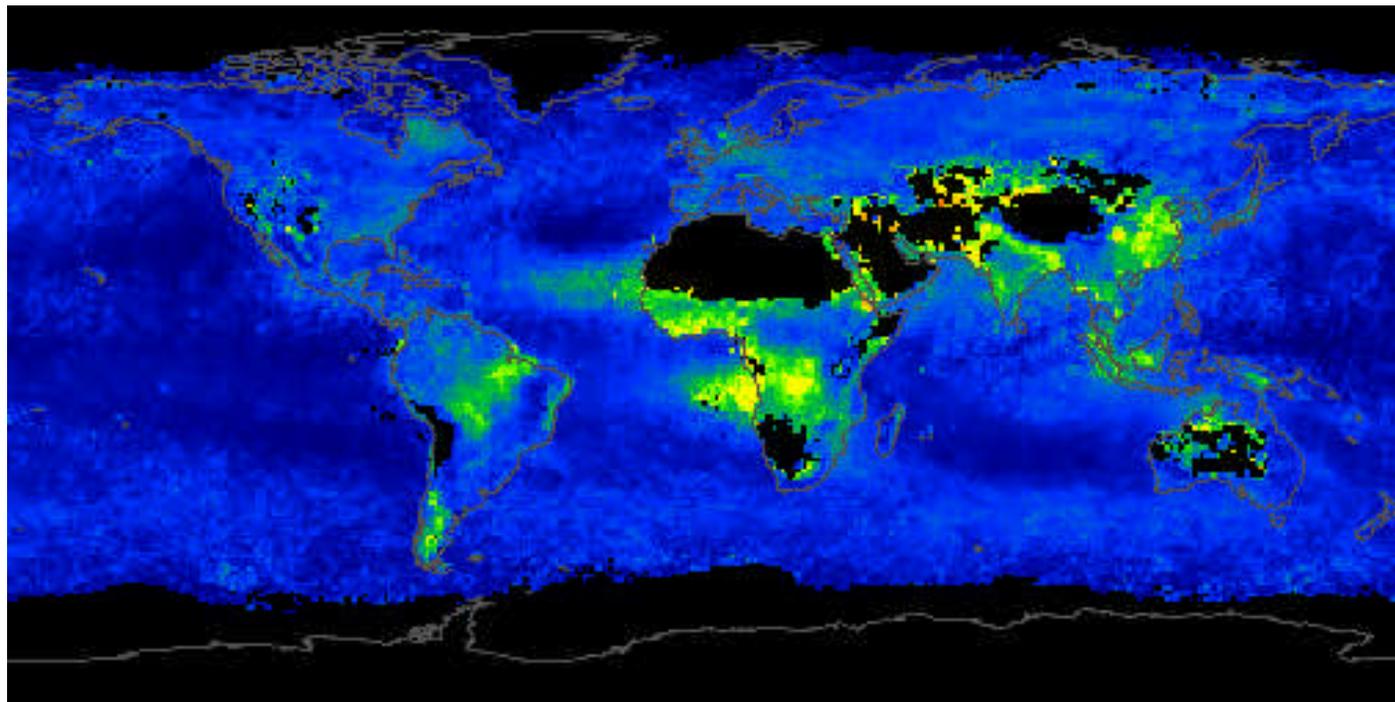
April 19, 2000



Global Aerosol Optical Thickness



Level-3 Monthly
September 2000

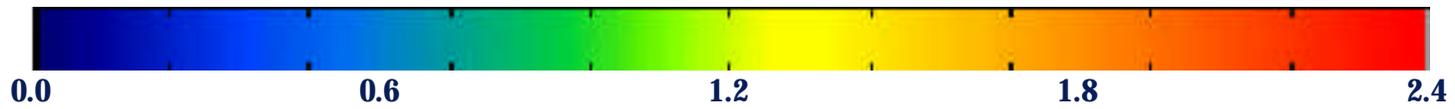
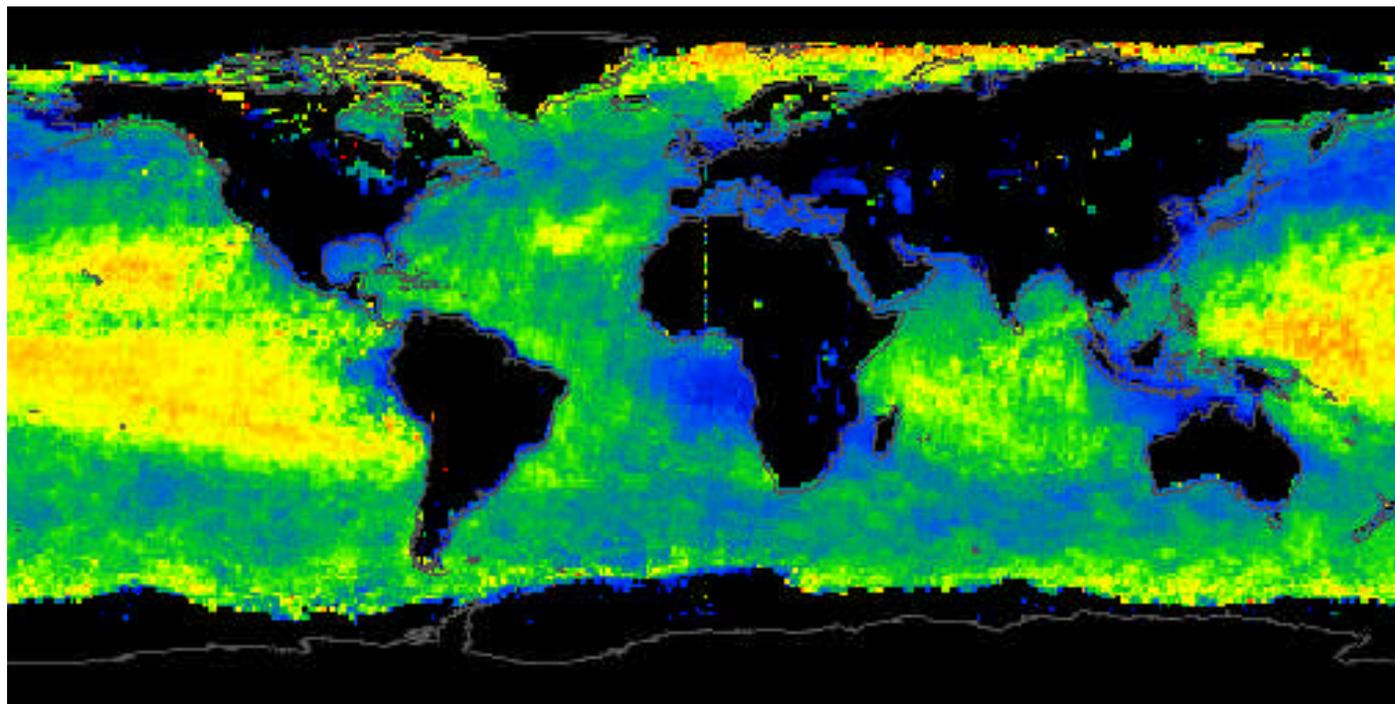


Aerosol Optical Thickness ($0.67 \mu\text{m}$)

Global Aerosol Effective Radius



Level-3 Monthly
September 2000



Aerosol Effective Radius (μm)



PRODUCTS

- OVERVIEW
- FLOW DIAGRAM
- HDF FILENAMES

Overview

Product Websites

More detail on each of the MODIS Atmosphere Products, outlined below, can be found on their respective home pages (product page links are located in the navigation bar (above) as well as in the summary outline (below)).



Ordering MODIS Data

Selected MODIS Atmosphere data products will be available to the public based on the following schedule:

Data Release Schedule				
Level-2 Products				
ESDT Name	Product Name	Release Date	Status	Available Dates
MOD04_L2	Aerosol	09/29/2000	Released	08/20/2000 & Later
MOD05_L2	Water Vapor	09/29/2000	Released	08/20/2000 & Later
MOD06_L2	Cloud	09/29/2000	Released	08/20/2000 & Later
MOD07_L2	Atmosphere Profile	11/27/2000	Released	10/21/2000 & Later
MOD35_L2	Cloud Mask	09/15/2000	Released	08/20/2000 & Later
Level-3 Products				
ESDT Name	Product Name	Release Date	Status	Available Dates
MOD08_D3	Daily Global	11/27/2000	Released	10/21/2000 & Later
MOD08_E3	Eight-Day Global	12/27/2000	Released	10/23/2000 & Later
MOD08_M3	Monthly Global	1/22/2001	Hold	11/2000 & Later

Click on the EOSDIS button (below) to acquire publicly released data:



o MODIS Atmosphere Web site:

<http://modis-atmos.gsfc.nasa.gov>

- Images
- Validation
- News
- Staff
 - » Resumes
- References
 - » ATBDs
 - » Validation Plans
 - » Publications (pdf)
- Tools
 - » Granule locator tools
 - » Spatial and dataset subsetting
 - » Visualization and analysis
- Data products
 - » Format and content
 - » Grids and mapping
 - » Sample images
 - » Acquiring data

Summary



- o MODIS provides an unprecedented opportunity for atmospheric studies
 - 36 **spectral** channels, high **spatial** resolution
- o Comprehensive set of atmospheric algorithms
- o Archive of pixel level retrievals and global statistics
- o Validation activities are high priority (ground-based, in situ, aircraft, and satellite intercomparisons)